

Economics of Navel Orangeworm Management in Almond and Pistachio Orchards

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Navel Orangeworm (NOW) infestations damage tree nuts, reduce grower revenue, require costly management practices to control, and threaten food safety and trade. We estimate that from 2018 through 2021, almond and pistachio growers spent an average of \$393 and \$262 per bearing acre, respectively, on winter sanitation and pesticide sprays targeting NOW. These costs are equivalent to 7.8% of almond and 3.7% of pistachio revenues.

Navel Orangeworm (NOW) is the top pest of California almonds and pistachios and affects other crops like walnuts, pomegranates, and figs. Female NOW moths lay their eggs on the fruiting bodies of tree nuts, and the resulting larvae burrow through the shell and eat the kernel. NOW damage is linked to aflatoxin contamination—a carcinogen—threatening food safety and exports to highly regulated key markets, such as the European Union.

To ensure product quality and food safety, nut processors—known as handlers—remove inedible nuts primarily caused by NOW damage. The share of inedible nuts delivered to handlers provides the best statewide estimate of NOW damage, which, for almonds, averaged 1.5% over the past two decades, as shown in Figure 1. However, a 2023 report from a major almond handler notes “excessive reject levels attributable to NOW... with levels running well into double-digit percentages for many loads.”

Handlers incur costs to remove damaged nuts and pay growers premiums based on the reject percentage. This means that NOW damage influences grower revenues from two angles:

first, the quantity of edible nuts they are paid for, and second, the resulting price per pound of edible nuts.

This article provides an analysis of NOW management practices and associated costs and benefits in almond and pistachio orchards. Our study focuses on years 2018 through 2021, including the most recent available pesticide use and cost data, and where appropriate, averages over four years to avoid bias caused by alternate bearing crop yields.

NOW Management Practices and Costs

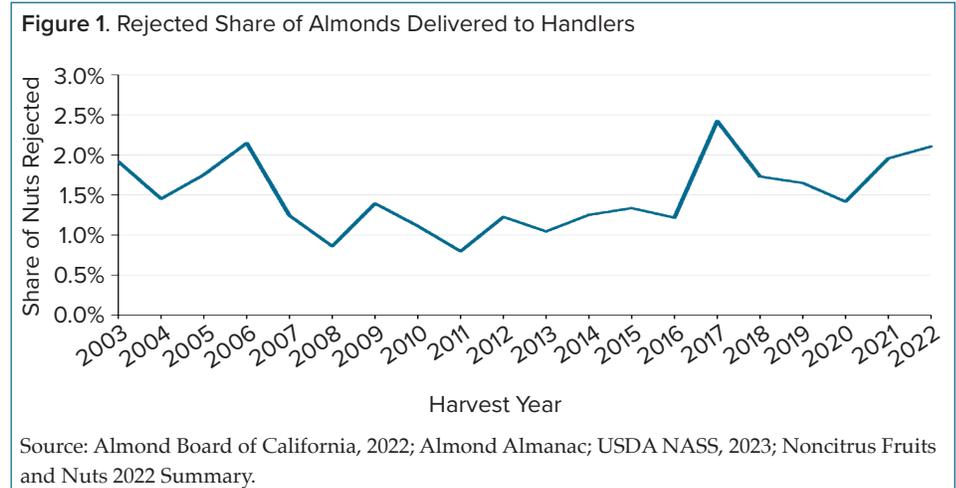
NOW larvae overwinter in the residual nuts in trees and on orchard floors from the previous harvest. These nuts are also known as mummy nuts. Moths emerge from mummy nuts around April, with subsequent generations emerging in late June/early July, August, and September. A new crop of tree nuts is safe from NOW infestation until the fleshy nut hull splits open, allowing moths access to the developing shell and kernel. Almonds reach the hull split stage in June/July, while pistachios split in August/September.

The primary tools available to growers to combat NOW damage include

winter sanitation, mating disruption, pesticide sprays, monitoring pest populations, and early harvest. When growers combine these and other practices to form an Integrated Pest Management (IPM) protocol, they can reduce the share of harvested meats rejected by the handler, leading to an increased yield of edible nuts and price premiums for quality, while minimizing negative environmental impacts from pesticides.

Winter Sanitation

Beginning as early as November, winter sanitation involves removing mummy nuts from trees and then gathering and destroying them before March. Using almond Cost and Return Studies published by the Department of Agricultural and Resource Economics at the University of California, Davis, we calculate that almond winter sanitation costs were approximately \$268 per acre. Assuming growers sanitize all bearing acreage, the annual average winter sanitation cost per almond-bearing acre is equivalent to 5.3% of the 2018–2021 average yearly revenues of about \$5,080 per acre in 2021 dollars. This cost includes labor, fuel, lube, repairs, and custom services associated with mechanically



shaking and hand poling mummy nuts from the trees, sweeping nuts into windrows, and shredding them with a mower.

In pistachio orchards, once the mummy nuts have been shaken to the ground and windrowed, growers destroy them alongside tree prunings, resulting in a winter sanitation cost of roughly \$138 per acre, equivalent to 2% of 2018–2021 average yearly revenues of \$7,000 per acre in 2021 dollars.

Despite being a foundational component of an effective NOW IPM program, winter sanitation is still challenged by weather and economic considerations. In a 2020/21 survey, about 82% of almond and 80% of pistachio growers reported using winter sanitation every year. Respondents reported that precipitation, which prevents growers from accessing fields with heavy equipment, is the top impediment to winter sanitation.

Using weather data and San Joaquin Valley (SJV) almond orchard locations, we calculate that precipitation in December 2022 through January 2023 was more than three times the average for the same months over the preceding twenty years. High winter rainfall in winter 2022–2023 may have hindered winter sanitation. Beginning winter sanitation in November is one strategy to mitigate the risk of high

rainfall, but that coincides with other orchard activities like pruning and weed control.

Furthermore, labor is a large share of winter sanitation costs, and recent changes to California labor laws have increased minimum wage rates and decreased the overtime pay threshold, resulting in higher labor costs for some growers. Using UC Davis Cost and Return Studies, we estimate that labor accounts for 25% of almond winter sanitation costs in the Sacramento Valley and northern SJV. This estimate includes the cost of equipment operator labor, manual labor, and labor provided by custom services. In the southern SJV, labor accounts for 75% of winter sanitation costs. This is due to the high reliance on hand poling to remove mummy nuts from trees to achieve the UC IPM recommendation for the region of less than one mummy nut for every five almond trees, compared to less than two per tree in the Sacramento Valley and southern SJV. From the 2020 South SJV Pistachio Cost and Return Study, we estimate that labor accounts for 54% of winter sanitation costs. Thus, increasing labor costs can have a substantial impact on NOW management costs.

Pesticide Applications

Pesticides play a vital role in NOW management in most tree nut

orchards, but applications require careful timing to coincide with moth emergence and hull split to be effective.

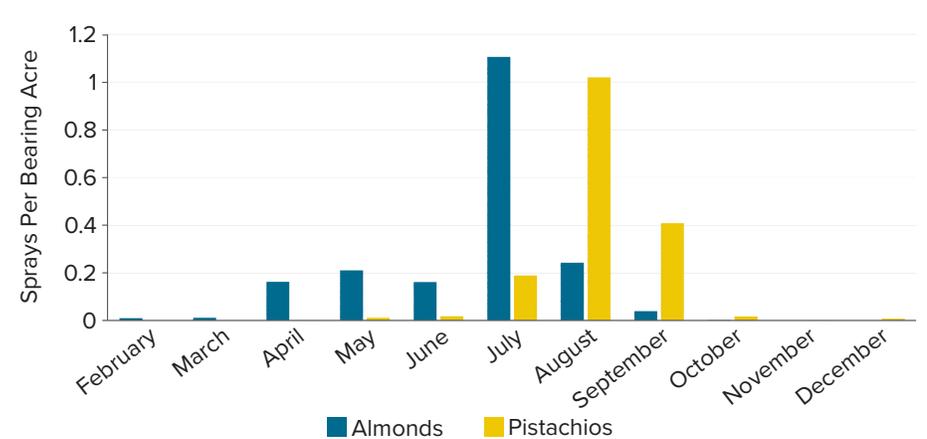
According to the UC IPM guidelines, almond orchards may require up to two pesticide sprays during hull split and a spring spray in orchards with a history of NOW damage. In pistachios, the UC IPM guidelines suggest spraying once during hull split and again when pest populations are high or when harvest is delayed. The number of pesticide applications has important operating cost implications, especially around peak application periods.

We use 2018 through 2021 data from the California Department of Pesticide Regulation (CDPR) to analyze the quantity and timing of products used to target NOW, distributor prices, and application costs from UC Davis Cost and Return Studies.

We find that, on average, growers apply 1.9 and 1.7 pesticide sprays targeting NOW per bearing acre per year in almond and pistachio orchards, respectively. Peak spraying activity occurs around hull split, as shown in Figure 2, when each almond and pistachio acre receives, on average, roughly one pesticide spray. Timing spray applications to coincide with hull split and moth emergence is critical to spray efficacy and requires daily monitoring of hull split progression and pest populations. Growers also use spring sprays to target NOW emerging from mummy nuts.

We estimate that the annual average pesticide materials plus equipment, fuel, and labor used to spray orchards equaled \$125 and \$124 per bearing acre of almonds and pistachios, respectively—equivalent to 2.5% of almond and 1.8% of pistachio revenues. Table 1 provides a breakdown of pesticide material and application costs.

Figure 2. Average Number of Pesticide Applications Targeting Navel Orangeworm Per Bearing Acre in 2018–2021



Source: Authors' calculations using CDPR Pesticide Use Reporting data.

Total spraying costs exhibit large variations across the state. Focusing on almonds, for which we have reliable county bearing-acreage data, we calculate the average spray costs by county and present the results in Figure 3. We find that growers in Fresno County use an average of 2.6 pesticide sprays targeting NOW per bearing acre per year and have the highest average expenditure on spray materials plus application costs, spending on average \$171 per bearing acre in 2018 through 2021. Fresno is the largest almond-producing county, with approximately 250,000 bearing acres out of the 1.3 million bearing acres in California in 2021.

Almond growers in the southern SJV spend more on NOW pesticides than their counterparts in the northern SJV and the Sacramento Valley. Glenn County is one exception, where growers use two pesticide sprays per acre at an annual average cost of \$127 per bearing acre, approximately double the average spray costs across other Sacramento Valley counties. Glenn County contained about 4% of the almond bearing acres in 2021.

Mating Disruption

NOW mating disruption is a relatively new pest management technology in tree nut production, with the first products appearing on the market around 2008. Mating disruption uses sex pheromones to confuse adult moths, interrupt mating patterns, and reduce the number of larvae that can go on to damage nuts. Growers hang mating disruption dispensers in the orchard canopy in March/April, and the devices emit pheromones throughout the growing season.

Mating disruption materials plus installation costs total about \$120 per acre. In a survey of growers, 25% of almond and 58% of pistachio growers report using mating disruption every year. Results from field experiments in Central Valley almond orchards show

about a 50% reduction in nut damage when mating disruption is used in combination with insecticides and winter sanitation compared to insecticides and sanitation only.

Cost of NOW Damage

NOW damage leads to a lower yield of edible nuts, with damaged nuts rejected and receiving no payment. In addition, the edible nuts receive a price premium or deduction based on the share of nuts rejected. Figure 4 (on page 8) presents examples of an almond and pistachio price schedule with respect to the percentage of inedible nuts rejected by the handler and shows a steep decrease in price per pound of edible nuts as the share of rejected nuts increases.

To quantify the total cost of NOW damage in almonds, we use the price schedule in Figure 4 and incorporate the almond industry rule of thumb that for every pound of damaged almonds delivered to the handler, an additional pound of damaged kernels is lost during harvest, hulling, and shelling.

Our analysis reveals that a reduction in the share of nuts delivered to the handler with NOW damage can significantly impact per-acre revenues. For instance, assuming an almond price before premiums and deductions of \$1.86 per pound, as in Figure 4, the handler rejects 3% of the nuts, and the yield of edible nuts is 2,150 pounds per acre. From these initial conditions, we estimate that reducing the share of

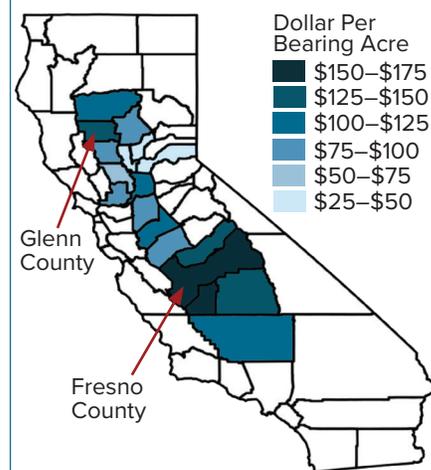
nuts damaged to 2% increases almond revenues by \$225 per acre, about a 5.6% increase in average 2018–2021 revenues. Reducing damaged nuts to 1.5% increases revenues by \$335 per acre, about 8.4%.

In the case of pistachios, we assume a base price of \$2.16 per pound, and that the handler rejects 3% of nuts and the yield of edible nuts is 2,800 pounds per acre. Reducing the share of nuts rejected to 2% in this situation could increase revenues by \$347 per acre, about 5.6%.

Comparing Farm Costs and Benefits of NOW Management

We estimate that in 2018 through 2021, almond growers spent \$393, and pistachio growers spent \$262, per bearing

Figure 3. Average 2018–2021 Spray Material Plus Application Costs Per Almond Bearing Acre Targeting NOW



Source: Authors' calculations.

Note: We exclude counties with less than 1,000 bearing acres of almonds. Prices in 2021 dollars.

Table 1. Average Annual Pesticide Sprays Targeting NOW Per Bearing Acre and Associated Costs in 2018–2021

	Almond	Pistachio
Number of Pesticide Sprays	1.9	1.7
Pesticide Material Costs	\$95.19	\$92.54
Pesticide Application Costs	\$29.94	\$31.50

Source: Authors' calculations using CDPR Pesticide Use Reporting data, University of California, Davis Cost and Return Studies, and pesticide prices from distributors.

Note: We calculate that average pesticide application costs per spray per acre equal \$15.36 in almonds and \$18.83 in pistachios. This includes the cost of fuel, lube, repairs, custom services, and labor. Annual average costs converted into 2021 dollars before averaging over years.

acre per year on average on winter sanitation and pesticide sprays targeting NOW. This represents a meaningful portion of annual operating costs for tree nut growers, especially in areas with high pest pressure.

Studies have shown that in some areas leaving two or more mummy nuts per almond tree regularly results in damage rates of 8% or higher. Thus, implementing a NOW IPM program that brings reject rates from 8% down to 2% would result in an increase in revenues of \$792 per acre in almonds (using the price schedule in Figure 4 and an initial edible nut yield of 2,150 pounds per acre). The increase in revenue can be broken down into two parts. First, an increase of \$524 per acre due to a higher edible nut yield of 2,440 pounds per acre sold at the original price (inclusive of deductions) of \$1.81 per pound. Second, an increase of \$268 per acre due to a higher price (inclusive of premiums) of \$1.92 per pound, paid for the higher yield of edible almonds.

We conducted a similar calculation for pistachios using a reduction in rejects from 8% to 2%, the price schedule in

Figure 4, and an initial edible nut yield of 2,800 pounds per acre. In this scenario, pistachio growers earn \$1,402 per acre in additional revenues, comprised of \$358 per acre from a higher edible nut yield of 2,980 pounds sold at the initial price of \$1.96 per pound, and \$1,044 per acre from the higher price of \$2.31 per pound.

Even in years with low tree nut prices, it is easy to see that the estimated returns from NOW IPM programs will likely outweigh the costs.

Almond NOW IPM Cost-Benefit Calculator

Effective NOW IPM protocols are critical to the sustainability of California tree nut industries. To help almond growers explore the costs and benefits of alternative IPM programs and damage percentages, we produced an online calculator that can be accessed by scanning the QR code below with a mobile phone. We plan to develop similar tools for pistachio and walnut growers in the future.

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Authors' Bios

Scott Somerville is a Ph.D. candidate and Brittney K. Goodrich is an assistant professor of Cooperative Extension, both in the ARE department at UC Davis. They can be reached at ssomerville@ucdavis.edu and bkgoodrich@ucdavis.edu, respectively.

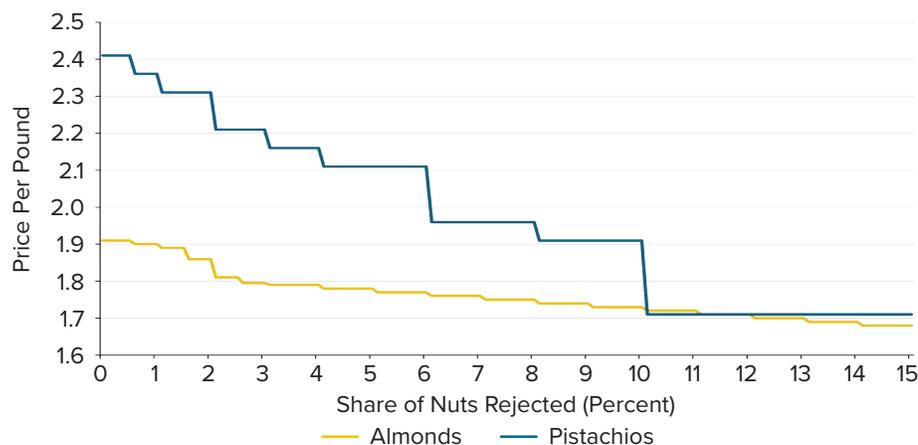
For additional information, the authors recommend:

Gordon, Phoebe E., Brittney K. Goodrich, and Houston Wilson. 2023. "Adoption of *Amyelois transitella* (Navel Orangeworm) Monitoring and Management Practices Across California Tree Nut Crops." *Journal of Integrated Pest Management* 14(1): 1–14. Available at: <https://bit.ly/3GI60On>.

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Machado, Mel. 2023. "Crop Progress Report—August 28, 2023." Blue Diamond Growers. Available at: <https://bit.ly/46FbKNL>.

Figure 4. Price Schedules With Respect to Share of Nuts Rejected



Source: Authors' calculations based on a premium schedule from a Central Valley pistachio handler (not publicly available) and almond premium schedules published in the Blue Diamond Growers 2021 Crop Delivery Information brochure. Available at: <https://bit.ly/3Rt3ADG>.

Note: In the almond price schedule, we assume deliveries to handlers contain 0.4% foreign material, and 3.6% chipped and broken nuts (informed by Blue Diamond Growers data from 2019–2022) and therefore achieve the second highest Nonpareil bonus, conditional on reject percentage. We use base prices of \$1.86 per pound of almonds and \$2.16 per pound of pistachios.

Scan QR code to visit:



NOW IPM Almond Calculator



Cost & Return Studies